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BOTANIC GARDENS AND TAXONOMY — THEIR ECONOMIC ROLE

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ABSTRACT

An account is given of how the development of botanic gardens and of taxonomy have been linked throughout much of their history. After the period of physic gardens in which botany and medicine were intimately associated, there came a phase of exploration and commercial and agricultural development of colonial territories by European powers in which botanic gardens and taxonomists played a vital role. In the twentieth century with the creation of separate agricultural institutions and research stations, botanic gardens lost their link with agriculture, and went through a phase of uncertainty and decline. With the rise of experimental botany, the role of taxonomy declined and efforts were concentrated on evolutionary or biosystematic, largely non-classificatory aspects, to the neglect of the information-processing role of the subject. In recent years, taxonomy is again seen to have a major practical role, in the conservation and resources crisis, a responsibility which taxonomists should willingly accept.

INTRODUCTION

If one peruses Leonard Huxley's 'Life and Letters of Sir Joseph Dalton Hooker' (1918), it is difficult not to be impressed by the countless references made by Hooker to economic botany or agriculture, whether it be reports on Indian tea plantations, cork oaks in the Punjab, the introduction of Liberian coffee to the West Indies, chocolate to Ceylon, ipecacuanha, mahogany, and cinchona to India, or the most extraordinary achievement of all, of transporting rubber plants from the Amazon and Orinoco to the Royal Gardens at Kew and then to Ceylon, thereby leading to the founding of the great rubber industry.

Again, Hooker strongly encouraged Sir Henry Barkly in his effort to save the forests of Mauritius from axe and fire, leading as in New Zealand and the Western Cape districts, to a decrease in rainfall and humidity. A hundred years later we have now got round to making the same sort of statement as part of recently re-awakened worldwide concern for the preservation of natural resources. It is ironic that the Secretariat for the Threatened Plants Committee and Survival Commission of the International Union for the Conservation of Nature and Natural Resources should be based at Kew and amongst its concerns are the threats to island floras such as Mauritius where out of 50 families so far revised for the 'Flore des Mascareignes', at least 25 angiosperm species are Endangered or Extinct. Many of the species are reduced to very small fragmentary populations, thus making their continued survival unlikely (Lucas, 1979).

In addition to all his preoccupations with the pressures of Kew, writing Floras and revisions, initiating *Genera Plantarum* and maintaining a vast correspondence, Hooker was very much concerned with botany as a practical science for the good of empire and mankind. Botany, agriculture and horticulture were all closely intertwined in his life. Botany and Botanic Gardens such as Kew were at the centre of a complex web of economic-practical (and even political) relationships. Similar networks, although on a lesser scale, existed in the other colonial powers such as France, Portugal and the Netherlands.

Much of the malaise that besets modern botany and in particular taxonomy and a large part of the explanation of its perennial image-seeking, stems from the divorce that has grown up between botany and agriculture and feverish attempts of botanists to seek respectability for their science, either as a branch of experimental science or of evolutionary biology, or, most recently as a part of molecular science. Nowhere in botany has this separating off of an agricultural/economic role had such a marked effect as in the case of botanic gardens and the science of taxonomy whose fortunes have been closely linked during the past few centuries. Suggestions will be made for taxonomists to accept a more positive role in human affairs. They, and botanists in general, will have to relearn much of their history if they are to have a viable future.

THE EARLY EUROPEAN BOTANIC GARDENS — THE LINK WITH MEDICINE

As Schultes (1972) has pointed out, the origins of botany are in medicine. For most practical purposes they were identical for much of man's history and "the witch-doctor — usually an accomplished botanist — possibly represents the oldest professional man in the evolution of human culture" Nowhere was this link more evident than in the earliest botanic gardens of modern times, founded in the mid-sixteenth century, which were devoted to the cultivation of medicinal plants, taking over the role, formerly occupied by the monastic physic gardens. The oldest botanic gardens (if one excludes those of the classic Chinese, Greek, Assyrian, Arabic and other early civilizations) were those established in Europe in Pisa (1543), Padua (1545), Florence (1545), Bologna (1547) and Zürich (1560), Leiden (1577), Leipzig (1579), Montpellier (1598), Paris (1597), Oxford (1621), Uppsala (1655), Berlin (1679), Edinburgh (1670).

The role of such medicinal gardens was to provide living specimens for the instruction of medical students and also for the supply of actual drugs for medicine. The founder of the first botanic garden, that of Pisa was Luca Ghini who was *lectura simplicium* in the University and thereby laid the foundation of modern pharmacognosy (Atkinson, 1955). To him must be attributed also the introduction of the herbarium. Although the first one was made by one of his pupils Michele Merini, Ghini was probably responsible for the practice of drying and pressing plants on paper (Stafleu, 1969), a technique which had a significant and far reaching consequence for the prosecution of taxonomy and for our general understanding of plant diversity.

As Stearn (1961) notes, there were no firm distinctions in those days between medicine, herbalism, pharmacy and botany, and what today we would call botanic gardens were then referred to as gardens of simples, apothecaries' gardens, physic gardens (cf. Chelsea Physic Garden), or in Latin, *hortus medicus* or *hortus botanicus*.

Although in these early medicinal gardens, the properties of some of the plants were, of course, known, having been recorded over the centuries in herbals, deriving from the classic work of Dioscorides *De Materia Medica* in the first century A.D. and its countless revisions over a period of 1500 years, in other cases, little, if anything, was known, about their value or properties, medicinal or otherwise, so that the investigation of their properties became a legitimate field of enquiry and indeed the acquisition of more and more different kinds of plants for cultivation in the botanic gardens became an end in itself, justified by the very fact that their properties were unknown and worthy of investigation.

This expansion of the holdings of the early physic gardens started a tradition continued by more recent botanic gardens which, of course, reflected the ever-increasing travelling and voyages of discovery undertaken in the seventeenth and eighteenth centuries, and the great scientific and economic expansion of the period. Details of the different waves of plant introduction have been well documented, notably by Kraus (1894), Hill (1915), Stafleu (1969) and Stearn (1961). Many of the important European gardens were founded in these periods of initial expansion, such as Copenhagen (1600), Groningen (1642), Oxford (1621), Utrecht (1639), Berlin (1679), Jena (1629), Halle (1698), Edinburgh (1670), Messina (1638/9), Tbilisi (1625), Uppsala (1655), Amsterdam (1682), Gottingen (1736), Caen (1736), Nany (1758), Coimbra (1772), Krakow (1783), Madrid (1781), Vienna (1754), Budapest (1771), Lenningrad (1713), Turin (1728/9), Siena (1784), Parma (1770), Palermo (1795).

THE FIRST TROPICAL BOTANIC GARDENS — THE LINK WITH AGRICULTURE AND TRADE

Not all botanic gardens were European even in the seventeenth and eighteenth centuries. Several were founded in the tropics. While the first botanic gardens of modern times were medicinal or physic gardens in origin, the first tropical botanic gardens to be established were originally collection stations or propagation centres for tropical plants, set up to further their introduction to cultivation locally or elsewhere. The early tropical botanic gardens were set up by the European powers on the trade routes to the orient, or in their possessions there or in the new world.

The Dutch founded a Garden at Capetown in 1694 and this was the first extra-European botanic garden' but the first, and what was to become one of the most celebrated, tropical botanic gardens to be created was that on Mauritius (Ile de France) in 1735 by the governor of the island, Labourdonnais, who bought the property known as Mon Plaisir and created a vegetable garden which was intended to supply his household, the town of Port Louis and ships which called in at the harbour. It was also used as a nursery for the introduction and acclimatization of plants of economic importance, amongst which was cassava which Labourdonnais introduced in 1736 to feed the slaves. His successor David created a second garden and property in 1746 called Le Réduit, Mon Plaisir being abandoned until 1753 when the horticulturalist Fusée-Aublet arrived to set up a drug house and create a botanic garden. The plants from Mon Plaisir were transferred to Le Réduit and a trials garden was set up there by Magon, the commandant-general of the two islands (Iles de France et de Bourbon). In 1767 P Poivre, a celebrated naturalist, was appointed as *Intendant* (administrator) of Mauritius and purchased the garden of Montplaisir in 1770. The ensemble of gardens formed the Parc des Pamplemousses into which many economically useful plants were introduced, notably spice plants which were taken from there to Réunion, Madagascar and Cayenne (cf. Davy de Virville & Schnell, 1954). This is the garden that later became known as the Jardin de Mon Plaisir (Mont Plaisir), Jardin de Pamplemousses and today the Royal Botanic Garden Pamplemousses.

Other early botanic gardens in the tropics were that at Saharanupur (1750) and Bangalore (1760) in India, and the first of a series of botanic gardens to be created in the West Indies were established on St Vincent and St Thomas (the Bath Garden) in 1764. Captain Bligh was commissioned to bring bread fruit to these gardens from Tahiti, an expedition leading to the celebrated Mutiny on HMS Bounty in 1781. An important botanic garden was started on Penang Island towards the end of the eighteenth century, the first of three to be founded there. There is considerable dispute about the date of the first Penang garden — 1800 according to Ridley (1910) but Purseglove (1958) notes that according to the latter author, "soon after the settlement of Penang in 1786, the East India Company decided to start spice gardens with a view to breaking down the Dutch monopoly of spice cultivation and trade. A botanist, Christopher Smith, was appointed in 1794 and in 1796 he was sent to the Moluccas to collect living plants of nutmeg and cloves. Ridley then adds that by 1800 the gardens contained 1300 plants and that they were greatly enlarged in that year when 15,000 clove and 500 nutmeg trees arrived from Amboina. It thus appears that the first Gardens were begun about 1796 and not in 1800 as usually stated". In 1787 Lt. Col. Robert Kyd founded the Calcutta Botanic Garden which, in his words, were "not for the purpose of collecting rare plants as things of curiosity or furnishing articles for the gratification of luxury, but for establishing a stock for disseminating such articles as may prove beneficial to the inhabitants as well as the natives of Great Britain, and which ultimately may tend to the extension of the national commerce and riches". (Kyd quoted in Gager, 1938). The Calcutta garden became a major botanical centre with an important herbarium and later the Botanical Survey of India was established there in 1890.

Another early and major tropical botanic garden is that of Bogor. In the Netherlands, after relative decline of natural sciences at the beginning of the nineteenth century, a consequence in part of the secretive colonial policy adopted by the United East India Company in the second half of the eighteenth century, according to Smit (1979), King William I realized the importance of the colonies for the Netherlands in supplying raw material and as a market for industrial goods (a lesson he had learned during his exile in England). Professor C. G. C. Reinwardt was appointed Director for Agriculture, Arts and Sciences in the Island of Java and Dependencies. He proposed the establishment of a botanic garden at Buitenzorg to carry out propagation trials on native plants so as to ascertain whether they were of potential value for commercial exploitation. Reinwardt's proposal was accepted and this led to the foundation of a Botanic Garden at Buitenzorg in 1817, today the Botanical Gardens of Indonesia at Bogor (Kebun Raya Indonesia). The collections of plants and animals which Reinwardt shipped to the Netherlands led to the establishment of a National Museum of Natural History in 1820 and eventually of the Rijksherbarium in 1829. Bogor's policy of collecting and maintaining new plants of economic potential for the development of agriculture persists to the present day. Amongst the plants introduced was *Elais guineensis* in 1848 which led to the plantations of high grade oil palm plantations of Indonesia and Malaysia.

In the five years following the founding of the Bogor Garden, several other important tropical Botanic Gardens were set up — Trinidad in 1819, Peradeniya in 1821 and the first Singapore Botanic Garden in 1822. The history of the Singapore Gardens which were later to play a major role in the development of the economy of S. E. Asia, is ably recounted by Purseglove (1958). The first Singapore Gardens were founded by Sir Stamford Raffles advised by Nathaniel Wallich who was visiting Singapore from the Calcutta Botanic Gardens. Nutmeg, cloves and cocoa were introduced by Raffles but the Gardens were short-lived, being closed in 1829 on instructions from India to cut back on expenditure (words that have a familiar ring today!). An Agri-Horticultural Society reopened then in 1836 and met the expenses from the sale of the nutmeg and cloves growing in there but a combination of pests and diseases and economic circumstances caused the closure of the Gardens in 1846.

The second Singapore Botanic Gardens were founded in 1859 through the efforts of a new Agri-Horticultural Society, but their main aims were to provide a pleasure garden, little more than a public park, until 1874 when the Society, then in debt, asked the Government to take over the Gardens for the benefit of the people of Singapore. In 1875 the Director of Kew, J. D. Hooker, was asked to recommend a suitable candidate as Superintendent. During the years 1875-1888, under the direction of Hooker's nominee James Murton, and later Nathaniel Cantley, both Kew-trained horticulturalists, the Gardens were greatly expanded and areas set aside for the cultivation of economic crops such as gutta-percha and rubber-producing trees, *Cinchona,* coffee, tea, sugarcane, etc. Timber trees were also introduced into the Garden and much of the tree planting in Singapore was supervised by the Gardens.

A year after Cantley's death, H. N. Ridley was appointed Director of the Garden and Director of Forests Straits Settlements. Ridley, who lived to be over 100, succeeded in making the Singapore Botanic Gardens a leading centre for the study of tropical botany and economic crops. He was responsible for showing that rubber trees could be tapped regularly and this together with his other experiments on the preparation of rubber and his advocacy of it as a plantation crop, "led to the foundation of the present industry in which so large a share of the wealth of Malaya and the eastern tropics has rested" (Purseglove, 1955).

Only a few Botanic Gardens were founded in Central and South America. Charles III of Spain organized the sending of an expedition under Martin Sessé to Mexico (Nueva España) in 1781, with one of the aims being the establishment of a botanic garden for instruction in botany and for the cultivation and preservation of the native products of the country. One of the members of the expedition, Vicente Cervantes, became Professor of Botany at the Department established in 1788 at the University of Mexico and took charge of the accompanying botanic garden. The inflow of exotic plants and seeds from America and Asia to Spain, where they could only be cultivated in the Royal Gardens of Madrid and Aranjuez, at great expense and with great difficulty in protecting them from the cruel winters, led to the establishment of the Jardín de Aclimatación de la Orotava, in the island of Tenerife by the Marqués de Villanueva del Prado in accordance with a Royal Order of 17 August 1788 by Charles III. The idea was that the climate of the Canary Islands would be more suited for the cultivation of these plants since it would be more similar than that of continental Spain to that of their native climes. The first consignment of seeds sent by order of the king, arrived in 1788 and the Garden has survived, after various vicissitudes, to the present day. The first South American garden was opened in Rio de Janeiro in 1808.

As we have seen, these early tropical botanic gardens had as a major role the introduction, cultivation and distribution of both native and exotic crops of potential value and promise, plus seedlings of valuable timber trees, as well as providing guidance and advice to the local settlers on how to grow and maintain the crops and keep them free from disease.

Another major role they played was in the foundation of a sound basis for research in tropical botany, and the directors and staff were usually heavily involved in plant exploration and in floristic and other botanical studies. As Purseglove (1958) rightly says, "the world owes these great pioneers a considerable debt"

COLONIAL EXPANSION, ECONOMIC BOTANY AND FLORISTICS

Referring to the British experience, Brockway (1979) in a provocatively entitled study called 'Science and Colonial Expansion: The role of the British Royal Botanic Gardens',* comments that the eighteenth and nineteenth centuries were "an era of economic botany, when the usefulness of new plants to the national economy was prominent in the minds of all but the purest taxonomists. Every new plant was being scrutinized for its use as food, fibre, timber, dye or medicine. Botanic gardens curiously served the state as well as science, and shared the mercantilist and nationalist spirit of the times". Kew and its satellite colonial gardens were to form the basis of a network of botanical stations, "stretching from Jamaica to Singapore and Fiji", which permitted the introduction and transfer of plant material from one part of the empire to another and produced the agricultural and technical knowledge needed for their successful cultivation. In this way, not only was the cultivation of spices such as cloves, pepper and nutmeg assured for the European market, but the basis of major agricultural patterns of world trade in crops such as coffee, tea, rubber, sugarcane, cotton, cacao, tobacco, pineapples and many others established.

This transporting of very large quantities of plants in the tropics which continued through the nineteenth century was not, as Purseglove (1958) points out, confined to economic plants. Plants of horticultural value were distributed freely between botanic gardens as part of the exchange system which gradually evolved along with the *Index Seminum* as one of the characteristic features of botanic gardens. With the expansion of interest in horticulture and gardening, both as trade and as a leisure activity, scientific institutions, private patrons, nurserymen and seed firms spent considerable sums in sponsoring expeditions by plant collectors to many parts of the world to seek out novelties for cultivation under glass and, when appropriate, for introduction into the trade.

The scale on which these exchanges took place is hardly conceivable today and the expense, difficulty and length of time spent transporting them must have been very considerable. Brockway (1979) makes the telling point that the exploratory voyages of the eighteenth and nineteenth centuries to which naturalist-explorers like Banks, Hooker, Darwin and many others were attached constituted "an almost unrecognized subsidy to natural science as important as any more formal government subsidy to science in our own time." This contributed not only to the collection of material of economic value for applied biology and agriculture but a vastly larger number of plants of no obvious economic value but vitally important for the expansion of systematic botany in general and incidentally, to the development and formulation of Darwin's theories of evolution by natural selection. Pure and applied science were inextricably mixed in these enterprises and the enormous benefits derived from government from the applied/agricultural side allowed the pure or academic aspects at least to be tolerated if not always specifically approved. In Britain, the enormous prestige attracted by Kew through its successful involvement in major economic and agricultural enterprises as part of imperial development, led to its widespread support by the political and commercial establishments. It even became regarded as the coordinating centre for botanical organization in Britain (Bower, 1913).

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* Brockway's book is a well documented study of the transfer of plants through the imperial network of British botanic gardens based on Kew but is marred by an uncritical anti-colonialist bias.

The official organ of the Royal Botanic Garden, Kew, since 1887 has been the *Bulletin of Miscellaneous Information* (later the *Kew Bulletin*) in which was published "information which comes to Kew in the course of official routine, and is likely to be of value and interest to the public". As succinctly described by Bean (1908) "Much of it deals with economic plants, old and new, and their products, actual and prospective. It discusses the introduction of such plants to British colonies and possessions, their cultivation, the preparation and manufacture of their products, market prices, and allied matters. This, perhaps, is its chief function, but it also publishes descriptions of new plants and discusses diseases of plants".

Indeed perusal of the early volumes of the Bulletin, brings home just how strongly "applied" the work of Kew was, yet paradoxically it is floristic taxonomic work, mainly on the plants of the colonies, with which the name of Kew became identified although this was in many ways an adjunct to its operations, rather than their raison d'être. Taxonomy was very much an applied, service science although, as I have argued previously (Heywood, 1980, 1982), as the decades went by and we passed into the twentieth century, less and less attention seems to have been paid to the precise needs of the consumer, with Floras and monographs being written in a style suited more for use by appropriately trained expatriate colonial botanists, agriculturalists, horticulturalists, foresters, etc., than by the local, educated public for whom they were presumably written.

THE DEVELOPMENT OF SCIENTIFIC BOTANY

This concentration by Kew and other official botanical institutions on systematic and economic botany did not meet with universal approval, especially as it coincided with a remarkable development of botanical activity in Germany, both in sheer numbers of scientists involved and the high quality of the research published. F. O. Bower (1938) in a retrospective look at British botany over a 60-year period, commented on the distorted effect that imperialism had had on the development of British botany, most of the resources of Kew, Edinburgh, Glasgow and British Museum being concentrated on recording the wealth of plants accumulated from Britain's vast colonial empire.

In effect, by the mid-nineteenth century, German universities had become pre-eminent in botanical studies in areas such as anatomy, embryology, cytology and reproduction, involving such figures as Hofmeister, von Mohl and Naegeli who outlined the basis of a unitary theory of plant structure, development and reproduction.

The leading position of German botanical science is attributed by Morton (1981) to the large number of universities in that country and to the fact that natural science was given equal weight with traditional disciplines such as theology, law and medicine. There were more professors and lecturers in botany in Germany than in any other country. Moreover, botany was treated in most German universities as an independent subject from medicine by the nineteenth century. The link with medicine persisted in other countries, including Britain, much longer, to the detriment of the development of botany as an independent natural science. The association with Pharmacy persists to the present day in countries such as Spain where there are usually chairs of botany in both the Faculties of Science and Pharmacy.

Another important factor in the rise of German botany was its relatively small imperial commitment, so that the one-sided development seen in Britain did not arise. From the point of view of taxonomy this had the further advantage that major official centres such as Berlin were free to develop research in systematic botany, unencumbered by the floristic needs of empire, and projects such as Adolf Engler's *Das Pflanzenreich* and *Die natürlichen Pflanzenfamilien* were to make their stamp on the taxonomic scene, with an influence almost as great as that of their 'experimental' colleagues in areas such as plant physiology.

The second half of the nineteenth century saw the development of major research schools in the German universities, especially those of Hofmeister, Sachs, de Bary, Pfeffer and Strasburger, to which British students (including Francis Darwin, F. O. Bower, I. Bayley Balfour, D. H. Scott, H. Marshall Ward and S. H. Vines) flocked for the privilege of working under such scientists of international reputation (Morton 1981), just as later in the mid-twentieth century they were to turn to well-endowed centres in the United States of America. In particular plant physiology developed and flourished as a major sub-discipline, rivalling and eventually overtaking morphology and systematics. In a period when German botanical science, textbooks and journals dominated the scene, it is not surprising that there was a movement in Britain to espouse the New Botany or "The Cause" as Marshall Ward called it, and bring it to British universities where outside systematics and plant geography, the subject of botany was virtually dead. With hindsight, it is evident that the very success of systematic botany and its domination of the scene during this period, was one of the main reasons for the low regard in which it was to be held throughout much of the twentieth century.

During the intellectual turmoil of the nineteenth century, Botanic Gardens in Europe expanded in number and usually in size, often adding an arboretum. Improved means of transport, the massive exchange of plant material already referred to, the development of glasshouses for the cultivation of tropical plants, and other technical developments led to the kind of botanic garden that became familiar to the present day — usually associated with a university, with a large collection of ornamental species (usually without proper record of their origin), often a collection of economic plants for display or teaching, order beds for instruction in systematic botany, and, with the divorce from their herbal/medicinal origin or from a later major economic role, their purpose became unclear. Many botanic gardens have disappeared — over 1,600 were estimated to exist in Europe alone at the end of the eighteenth century and in the following centuries many more were established but only about 600 exist in the world today. As we shall see, the fortunes of taxonomy were affected by these same factors and closely paralleled to those of the botanic gardens.

DARWINISM, BOTANIC GARDENS AND TAXONOMY

Botanic gardens were scarcely affected by the impact of Darwinism and the rise of evolutionary studies, even although some of the leading protagonists were members of the tightly knit coterie of British scientists including Hooker, Huxley and others. The practice of taxonomy was likewise little changed by the Darwinian revolution although a new theoretical basis had been provided (Heywood, 1974). There were, however, two deleterious effects. On the one hand, evolutionary theory provided an aura of respectability for taxonomists — classifications (although not changed in substance) were no longer to be regarded as static but as reflections of the dynamic evolutionary processes. There was a failure, not resolved until about a century later, to distinguish between classification being made possible by evolution and classification being based on evolution. This led to a period of phylogenetic excesses in which these were almost feverish attempts to place each organism on a phylogenetic tree even though no information about evolutionary processes was known. It can be argued that much of the body of eclectic, so-called phylogenetic studies engendered by Darwinism actually hindered taxonomy and classification. On the other hand, the concentration of effort on phylogenetic studies diverted attention away from the practical, information-processing side of taxonomy, a rôle which many taxonomists, until recently, either refused to acknowledge or considered as unworthy of consideration by evolutionary scientists and best left to the herbarium or museum worker. Consequently the theory and methodology of taxonomy was largely neglected for most of the nineteenth and twentieth centuries — until the late 1950's, with the rise of phenetic taxonomy, taximetrics and biochemical systematics and the publication of the first modern text books of taxonomic principles (eg. Cain, 1959 ; Cain and Harrison, 1958, 1960 ; Gilmour, 1961, Heywood and McNeill, 1964 ; Davis and Heywood, 1963 ; Sokal and Sneath, 1963 ; Alston and Turner, 1963 ; Simpson, 1963).

One consequence of Darwinism on plant systematics was to stimulate research into the origin of the angiosperms and to construct systems of classification of the flowering plants, aimed at that elusive goal 'the natural system'. Bentham and Hooker's *Genera Plantarum* which was essentially a pre-evolutionary system of classification was adopted throughout Britain and its colonial territories. Again there was a rival development in Germany. Adolf Engler, leader of the Berlin school of plant taxonomy and geography, Director of the Berlin Museum and Botanic Garden, in association with K. Prantl, Director of the Breslau Botanic Gardens, published *Die natürlichen Pflanzenfamilien* (1887-1915), an account of the entire plant world down to generic level which has been described as epitomizing in botany the unprecedented cultural and social revival of Germany in the second half of the nineteenth century (Stafleu, 1972). Not only was this encyclopaedic undertaking a symbol of the spectacular development of plant systematics in Germany in the late nineteenth and early twentieth centuries, but it was in a sense the first evolutionary system of classification of plants, albeit based on a series of anagenetic grades of advancement or specialization rather than on common ancestry and tree-like branching patterns (cladistics). Engler and Prantl did not in fact provide a tree diagram of their system. *Die natürlichen Pflanzenfamilien* was widely adopted in continental Europe and elsewhere, especially in its later versions and the fact that the system started off with apetalous catkinate groups in contrast with polypetalous thalamiflorous groups only served to heighten the debate over the nature of the primitive flower. It should be noted in passing that North American Bessey produced a deliberately "phylogenetic" system in 1915 (based on earlier versions of 1893 and 1897) which was more similar to Bentham and Hooker than to Engler and Prantl in its concept of the primitive flower.

The main practical value of these systems *qua* systems, as opposed to their information content, is, and was, that they provide a sequence or arrangement of families which can be followed by Herbaria, Floras, etc. It is, therefore, curious how these so-called phylogenetic systems seemed to occupy such a prominent role in plant systematics over the past hundred years even though very few botanists were engaged in their actual construction. It is as though plant taxonomists need to perceive some sort of goal to give meaning to their studies. Furthermore, the work of many chemical or biochemical contributions to plant systematics seem, for reasons not easy to comprehend, to be aimed at assisting in the elucidation of phylogenetic relationships within the angiosperms. I have suggested (Heywood, 1973) that this is largely the fault of plant systematists who present a false picture to the outside world of both the state of angiosperm phylogeny and of the role that it plays in systematics.

THE DECLINE OF BOTANIC GARDENS AND TAXONOMY IN THE TWENTIETH CENTURY

After their zenith in the latter half of the nineteenth century, botanic gardens generally went through a phase of decline and lack of purpose in this present century. This was partly caused by development in most tropical territories of independent agriculture or forestry departments and much of the work on introduction and testing of crops and other plants of economic importance was taken over by them, leaving the botanic gardens without one of their major roles. As Purseglove (1958) comments, many of the tropical botanic gardens were absorbed into the new agricultural departments, often with disastrous results to the research in botany previously undertaken by them. "The role of tropical botanic gardens in fostering agricultural development in many tropical countries, usually with very small staff and slender resources, is now forgotten". Forgotten too is that many of these staff were professional taxonomists who saw their role as much wider than commonly viewed today. Popenoe (1945) likewise remarks that the beginnings of experiment station work in tropical America go back to the establishment of botanic gardens in the British colonies. The removal of a major role in agricultural development and introduction applied equally well to Botanic gardens outside the tropics, especially in Europe with the development of separate agricultural research institutions, agricultural departments in universities, etc.; and the subject of economic botany also went into decline, only recently showing signs of revival as an academic discipline and as one of the functions of botanic gardens, along with the related field of ethnobotany.

The pattern that emerges for plant taxonomy as the present century advanced is quite complex. On the one hand, practical or classical taxonomy largely became the preserve of the official institutions such as the state herbaria and museums, especially in countries such as Britain and France, which were largely committed to a series of projects, mainly floristic, arising out of former colonial links. Thus even though the role of economic botany diminished greatly, much of the inventory work (Floras are basically inventories of plant resources of an area) continued and persists to the present day. Monographic studies on many groups were undertaken. University taxonomists, on the other hand, tended more and more to concentrate their efforts on the more scientific disciplines related to systematics or evolutionary studies such as biosystematics, experimental taxonomy, genecology, the New Systematics, etc. In most British universities, formal taxonomic studies showed a marked decline, even being forbidden in some cases. In continental Europe especially in southern countries such as Portugal, Spain, Italy and France, efforts were concentrated on phytosociology, a sort of amalgam between floristics and ecology, while in Britain and Scandinavia (like North America) the thrust of research was in experimental taxonomy and experimental ecology, the descriptive aspects of both subjects being neglected.

The taxonomy of crop plants and horticultural taxonomy became a minority specialized subject, and a much neglected one, with only a few institutions or individual taxonomists becoming involved.

THE CONSERVATION PHASE — NEW RESPONSIBILITIES

During the past fifteen to twenty years there has been a major resurgence of floristic taxonomy throughout the world (Heywood, 1982), not all based on the official institutions.

This has stemmed partly from a gradual recognition that floristic work is an essential precursor of conservation activities which have become a major preoccupation, not only of biologists but even of governments in recent years, following the realization of the massive scale on which plant resources, such as forests (especially in the humid tropics) are being converted to other use, consumed or destroyed (National Academy of Sciences, 1980a). This has dramatically foreshortened the time-scale against which taxonomists have to operate — we now have decades, rather than centuries to complete even our basic floristic inventory.

Botanic gardens, too, have now sought a new role in conservation and resource studies, one which is not too-dissimilar from that of their economic/agricultural role of the eighteenth and nineteenth centuries (Simmons *et al.*, 1976; Synge and Townsend, 1979). The difference this time is that conservation and resource studies on the major crop species is being undertaken by other bodies such as the International Plant Genetic Resources Board (itself responsible for sponsoring plant collecting expeditions in the tradition of the nineteenth century) and various gene banks, while botanic gardens are concerned with the vastly wider range of actually or potentially threatened of endangered species, often of no known economic importance (although the potential is there) but of scientific or horticultural importance.

The future of botanic gardens and plant taxonomy is again linked, this time in the common goal of floristic inventory, conservation and resource studies. What then are the lessons to be learned from this situation? In a recent commentary, Bradshaw (1982) states that the future of ecology and of ecologists is going to depend to a large extent on being prepared to face up to the challenges involved in applying it to the real world. This is equally true for taxonomy and taxonomists. As we have seen in this paper taxonomy did play a useful, practical role in response to demands made on it in the past. It is only in the last half century or so that it has largely turned its back on its practical role, even to some extent in the national institutions whose function is largely to respond to public demands.

In particular, the role of taxonomists in the environmental crisis has only belatedly been recognized and there has been a failure to accept fully our responsibilities in this area.

For example, when one looks at the response of the major institutions to the conservation and resources crisis, the picture that emerges is discouraging. Small groups have been set up to deal specifically with conservation, often very successfully, such as the Office of Biological Conservation at the Smithsonian Institution, Washington, or the Conservation Unit (and associated with it the Threatened Plants Committee Secretariat of IUCN/WWF) at Kew, leaving the majority of staff to carry on their taxonomic research unaffected by such matters. What are the great issues that have galvanized the Museums of the world today? The answer, it would seem, is cladistics, whether Hennigian or transformed, which has generated more heat than light and regrettably little of practical value. Anything less calculated to attract support for taxonomy and its objectives is difficult to imagine. This is not to deny the need for investigation into the theoretical and practical bases of classification and systematics, but surely not to the detriment of the effective prosecution of the subject as the cladistic debate shows signs of becoming almost an end in itself and even more sterile than the bibliographic/nomenclatural scholasticism for which the great Museums and Herbaria have been castigated in the past.

Likewise there has been little commitment from most academic taxonomists, as opposed to a general sympathy for the cause of conservation. All too often the response is that there is little if anything that the individual taxonomist can do, or that the matter is one for politicians, economists or governments, not scientists. Yet the taxonomist is often uniquely qualified to know the relevant basic facts about a particular conservation situation, having either direct field knowledge or access and ease of familiarity with the highly specialized literature.

Relevant again to the taxonomic situation are Bradshaw's (1982) comments on achieving useful ecology — "Although most of us, I guess, would prefer to be left to share our own ideas it is abundantly clear that the world demands that we *use* science more, for practical ends". Ecology is popular at present because it is seen to be of actual or potential value to many people. Taxonomy has yet to achieve such a popularity today although it did so last century. What do we need to do ? The following is a summary of various suggestions I have made in recent years.

(1) We must reconsider the role of the taxonomist in the environmental crisis and adopt a positive rather than a passive attitude.

(2) We must learn to work more closely with ecologists, conservationists, environmental managers, geographers, etc. in assembling information about species, areas, communities, ecosystems which, for whatever reason, are at risk or about which decisions require to be made which may affect their long term future (Heywood, 1975).

(3) Closer collaboration should be urged between taxonomists and agronomists and plant breeders in areas such as exploration of genetic resources, collecting material for seed banks and living collections (Heywood, 1976).

(4) We must pay much more attention to identifying the needs of the users of taxonomy and take care to make the vehicles of publication such as Floras, handbooks etc. as suited as possible to these needs and not just design them for other taxonomists. There is a need for more effective communication. As Jacobs (1976) has stated bluntly 'Taxonomists certainly have to unlearn a lot of indifference to the consumers of their work. Terminology should be in more plain English and consistency strived for".

(5) We must accept our role as custodians of a general biological information system and devote much more effort to the practical information storage and retrieval side of our business, using electronic data processing where appropriate.

(6) We must assess the overall situation facing taxonomy today in the light of the world-wide threat to plant resources and establish priorities amongst our various activities, which take full account of the obligations we have to the community from which we ultimately derive our support and finance and undertake international cooperation and coordination on a much more effective scale than hitherto. For too long we have adopted a serendipity approach to taxonomic and systematic research (Heywood, 1977 ; Heywood and Clark, 1982, National Academy of Sciences, 1980).

(7) We must keep under review the training requirements for taxonomists. We need to assess the different kinds of workers needed in today's taxonomy and this in turn requires a critical analysis of the various kinds of activity in which we are to be engaged in the next few decades.

CONCLUSIONS

The view I have put forward in this paper is that the development of taxonomy in many parts of the world has been closely linked with that of botanic gardens. So long as the link with medicine existed, botany and in particular taxonomy shared some of the privileged status accorded to medicine.

With the creation of empires, better communications, the opening up of continents by railroads, and the industrial revolution, there was a great flowering of floristic taxonomy as the economic role of plant exploration and introduction became dominant, reaching its peak in the latter half of the nineteenth century. Without this, plant taxonomy would not have received the enormous support and prestige that it held during this period.

With the loss of the link with medicine and the stripping away of the economic-agricultural role, botany (and botanic gardens) and taxonomy became a pure science and part of the experimental, evolutionary, latterly molecular biological scene while the only remaining applied role, for taxonomy that of information handling and processing for biology (and for other fields), was neglected or even rejected.

Today with the realization that plant resources and conservation studies are utterly dependent on accurate floristic and taxonomic studies, taxonomy has the opportunity again of receiving major support. It will only do so if taxonomists are prepared to respond to the demands made on them by society and not dissipate major parts of their energies debating matters such as cladistics and phylogenetic reconstruction without a commensurate return in terms of increased knowledge of plant and animal groups.

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